Stoller Hanford Office

DOE-EM/GJ1018-2005

299-W18-08 (A7525)
Log Data Report

Borehole Information:

Borehole:	299-W18-08 (A7525)		**Site:**	216-Z-12 Crib		
Coordinates (WA State Plane)		**GWL (ft)**[1]:	Not measured	**GWL Date:**	None	
North	**East**	**Drill Date**	**TOC**[2] **Elevation**	**Total Depth (ft)**	**Type**	
566359.302	135446.972	01/67	685.47	212	Cable	

Casing Information:

Casing Type	**Stickup (ft)**	**Outer Diameter (in.)**	**Inside Diameter (in.)**	**Thickness (in.)**	**Top (ft)**	**Bottom (ft)**
Welded steel	0	6 5/8	6 1/8	1/4	0	48

Borehole Notes:

This borehole was drilled to 212 ft in 1967 using a 6-in. casing. At the present time, the borehole is open only to 48 ft.

Casing diameter and casing stickup measurements were acquired by the logging engineer using a caliper and steel tape. Measurements were rounded to the nearest 1/16 in.

All logging measurements are referenced to the top of casing, which is at ground level.

Logging Equipment Information:

Logging System:	Gamma 4E		**Type:** SGLS (35%) 34TP40587A
Effective Calibration Date:	12/21/04	**Calibration Reference:**	DOE-EM/GJ854-2005
		Logging Procedure:	MAC-HGLP 1.6.5, Rev. 0

Logging System:	Gamma 4I		**Type:** Passive Neutron U1754
Calibration Date:	None	**Calibration Reference:**	None
		Logging Procedure:	MAC-HGLP 1.6.5, Rev. 0

Spectral Gamma Logging System (SGLS) Log Run Information:

Log Run	**1**	**2**	**3**	**4**	**5 Repeat**
Date	09/08/05	09/08/05	09/08/05	09/08/05	09/08/05
Logging Engineer	Spatz	Spatz	Spatz	Spatz	Spatz
Start Depth (ft)	48.0	30.0	24.5	20.0	26.0
Finish Depth (ft)	30.0	20.0	24.5	1.0	23.0
Count Time (sec)	100	200	1000	100	200

Log Run	1	2	3	4	5 Repeat
Live/Real	R	R	R	R	R
Shield (Y/N)	N	N	N	N	N
MSA Interval (ft)	1.0	0.5	stationary	1.0	1.0
ft/min	N/A[3]	N/A	N/A	N/A	N/A
Pre-Verification	DE901CAB	DE901CAB	DE901CAB	DE901CAB	DE901CAB
Start File	DE901000	DE901019	DE901040	DE901041	DE901061
Finish File	DE901018	DE901039	DE901040	DE901060	DE901067
Post-Verification	DE901CAA	DE901CAA	DE901CAA	DE901CAA	DE901CAA
Depth Return Error (in.)	N/A	N/A	N/A	0	0
Comments	No fine-gain adjustment.	No fine-gain adjustment.	Location of highest count rate interval.	No fine-gain adjustment.	No fine-gain adjustment.

Passive Neutron Logging System (PNLS) Log Run Information:

Log Run	6	7 - Repeat			
Date	09/12/05	09/12/05			
Logging Engineer	Spatz	Spatz			
Start Depth (ft)	47.0	27.0			
Finish Depth (ft)	1.0	23.0			
Count Time (sec)	100	100			
Live/Real	R	R			
Shield (Y/N)	N	N			
Sample Interval (ft)	1.0	1.0			
ft/min	N/A	N/A			
Pre-Verification	DI242CAB	DI242CAB			
Start File	DI242000	DI242047			
Finish File	DI242046	DI242051			
Post-Verification	DI242CAA	DI242CAA			
Depth Return Error (in.)	0	0			
Comments	None	None			

Logging Operation Notes:

Pre- and post-survey verification measurements for the SGLS were acquired using the Amersham KUT (^{40}K, ^{238}U, and ^{232}Th) verifier with serial number 115. A centralizer was installed on the sonde.

The relatively higher activity interval from 20 to 30 ft and the repeat section from 23 to 26 ft were logged at 200 second counting times at 0.5-ft intervals. A stationary measurement was acquired for 1,000 sec at 24.5 ft. The remainder of the borehole was logged at the normal 100 seconds at 1.0-ft intervals.

Passive neutron logging was also performed in the borehole. This logging method has been shown to be effective in qualitatively detecting zones of alpha-emitting contaminants from secondary neutron flux generated by the (α,n) reaction and may indicate the presence of transuranic radionuclides.

Analysis Notes:

Analyst:	Henwood	**Date:**	10/20/05	**Reference:**	GJO-HGLP 1.6.3, Rev. 0

SGLS pre-run and post-run verification spectra were collected at the beginning and end of the day's logging. All of the SGLS verification spectra were within the acceptance criteria. Examination of data indicates that the detector functioned normally during logging, and the data are accepted.

An AmBe neutron source was used for verification measurements with the passive neutron logging system. Currently there are no verification criteria established for this system. The counts obtained from the pre and post verifications were within 1 percent.

Log spectra were processed in batch mode using APTEC SUPERVISOR to identify individual energy peaks and determine count rates. Verification spectra were used to determine the energy and resolution calibration for processing the data using APTEC SUPERVISOR. Concentrations were calculated in EXCEL (source file: G4EApr05.xls). A casing correction for 0.25-in.-thick casing was applied to the SGLS data. No corrections for dead time or water were required.

Results and Interpretations:

Log data for this borehole indicate the presence of the radionuclides ^{233}U, ^{232}U, and ^{237}Np. The existence of ^{239}Pu reported in 1998 by prior spectral gamma logging cannot be confirmed. It is believed the uranium resulted from thorium campaigns whereby natural ^{232}Th was irradiated in a reactor for the primary purpose of generating ^{233}U. At least two special processing campaigns in the PUREX plant are known to have recovered ^{233}U from thorium between 1966 and 1971 (DOE 1987). ^{237}Np is most likely a reactor product created separately from the ^{233}U. Although ^{233}U is a daughter of ^{237}Np, ingrowth of ^{233}U from ^{237}Np will be extremely slow, and the observed ^{237}Np activity is not sufficient to account for the existence of detectable ^{233}U, given the maximum time span of 40 to 60 years.

^{233}U can be created in a reactor using a thorium target by the reaction:
^{232}Th (n,g) $\rightarrow$ ^{233}Th (β) $\rightarrow$ ^{233}Pa (β) $\rightarrow$ ^{233}U.

Decay chains for ^{237}Np/^{233}U and ^{232}Th/^{232}U with primary decay modes and half lives are shown in the equation below.

^{233}U has a half life of approximately 160,000 years and decays by alpha emission to ^{229}Th, which has a half life of 7,880 years. Subsequent decay products have very short half lives (milliseconds to days). The attached ^{233}U ingrowth chart illustrates the calculated ingrowth of ^{233}U decay products. Primarily because of the long half life of ^{229}Th, the first decay product of ^{233}U, secular equilibrium of ^{233}U with its daughters is not reached for approximately 30,000 years. Equilibrium is a condition where the rate of production of a nuclide by radioactive decay equals the rate of decay of that nuclide. In other words, in an equilibrium condition, the activity of a daughter product will equal the activity of the parent. Because the ^{233}U was created recently (i.e., approximately 40 years ago), equilibrium has not been reached. However, the short-lived decay products are in equilibrium with ^{229}Th. Note that the equilibrium activity of ^{209}Tl will be lower because of the 2% branching ratio.

A plot of energy peaks detected by the SGLS that exist in the ^{233}U decay chain is included. In this plot, scatter is observed where the calculated concentrations should be approximately the same. This scatter is due to the low yields of the gamma rays and interfering gamma rays from other radionuclides. For example, the ^{209}Tl 465.13 keV energy peak (yield of 96.9%) is probably receiving counts from the 464.95 keV ^{224}Ra (yield of 0.018%) and the 463.0 keV ^{228}Ac (yield of 3%), both of which are decay products of naturally occurring ^{232}Th and/or ^{232}U. The ^{213}Bi 440.46 keV energy line (yield of 26.1%) appears to best represent the concentration and has no obvious interferences.

The estimated concentration of ^{213}Bi is approximately 3.5 pCi/g. As observed from the ^{233}U ingrowth chart, this is consistent with a ^{233}U concentration on the order of 1,000 pCi/g after 40 years.

^{232}U is created in the reactor with ^{233}U as a result of secondary reactions when a thorium target is irradiated. Two likely reactions include:

^{232}Th (n,2n) $\rightarrow$ ^{231}Th (β) $\rightarrow$ ^{231}Pa (n,g) $\rightarrow$ ^{232}Pa (β) $\rightarrow$ ^{232}U

^{232}Th (n,g) $\rightarrow$ ^{233}Th (β) $\rightarrow$ ^{233}Pa (β)$\rightarrow$ ^{233}U (n,2n) $\rightarrow$ ^{232}U

Both ^{232}U and ^{232}Th decay to ^{228}Th, the first decay product of ^{232}U and the third decay product of ^{232}Th. ^{228}Th and the radionuclides lower in the decay chain will be in equilibrium with both parents. ^{232}Th is long lived and naturally occurring so that equilibrium has been attained long ago. ^{232}U has a half life of 68.9 years and the ^{232}U ingrowth chart indicates that decay products will quickly reach equilibrium with the parent ^{232}U. Therefore, the concentration determined for each decay product from ^{228}Th to ^{208}Tl will reflect decay from both parents. In spectral gamma log analysis, the 2615-keV ^{208}Tl gamma ray is used to represent the concentration of the naturally occurring parent ^{232}Th. This gamma ray is energetic relative to gammas emitted by the other daughter products and its yield of approximately 35% results in easy detection. Because the concentrations of the ^{232}Th decay products below ^{228}Th are magnified by decay products of ^{232}U, the natural component of ^{232}Th must be determined from its second decay product (^{228}Ac). ^{228}Ac can be directly measured using the 911 and 969-keV gamma rays. A comparison plot of energy peaks detected by the SGLS in the ^{232}U and ^{232}Th decay chains is presented. The disruption of the equilibrium in the natural ^{232}Th decay chain is apparent where all of the decay products below ^{228}Ac exhibit elevated concentrations between approximately 23 and 27 ft in depth.

To determine the concentration of ^{232}U, the activity due to natural decay of ^{232}Th must be subtracted. The ^{228}Ac concentration calculated from the 911-keV energy peak is subtracted from the ^{232}Th concentration based on the 2615-keV ^{208}Tl energy peak. The result is a maximum concentration of approximately 3.5 pCi/g ^{232}U. For the naturally occurring ^{232}Th, the 2615-keV peak is used to calculate concentrations except for the interval from 23 to 27 ft where ^{228}Ac is used. Using an estimated age of 40 years and current concentration of 3.5 pCi/g, it is estimated the original concentration of ^{232}U was approximately 5 pCi/g.

^{233}Pa is the first decay product from alpha decay of ^{237}Np. ^{233}Pa is detected in spectra acquired in this borehole by at least five prominent energy peaks at approximately 300, 312, 375, 398, and 416 keV. A comparison plot of energy peaks detected by the SGLS of ^{233}Pa strongly suggests most, if not all, of the energy counted at these energy peaks is attributable to ^{233}Pa. The maximum concentration determined for ^{233}Pa using the 312-keV energy peak (highest yield of the peaks at 38.6%) is approximately 60 pCi/g, which reflects the parent ^{237}Np concentration.

The decay of ^{237}Np at 60 pCi/g cannot account for a ^{233}U concentration of approximately 1,000 pCi/g. As observed from the ^{237}Np ingrowth chart, it is apparent the ^{233}Pa, with a short half life of 26 days, almost immediately reaches equilibrium with its parent. ^{233}U will not reach equilibrium with ^{237}Np for more than 800,000 years. Because the maximum age of the ^{237}Np is 40 to 60 years, the amount of ^{233}U accumulated from decay of ^{237}Np would be negligible. Therefore, the ^{237}Np and ^{233}U observed in this borehole most likely originate from separate sources.

The final figure represents a summary of the decay of the three primary radionuclides (^{237}Np, ^{233}U, ^{232}U) detected or inferred to exist at the present time. In addition, ^{233}U that will result from the decay of ^{237}Np is shown. ^{229}Th, a relatively long-lived decay product of ^{233}U, is shown for both the current activity of ^{233}U and for what will be produced from the ^{237}Np to ^{233}U decay.

The passive neutron detector indicated no significant neutron flux in the survey depth interval. In addition, there is no evidence of neutron capture gamma rays, such as the 2,223-keV hydrogen capture gamma line, which would indicate a significant neutron flux. Slight elevation in count rate (0.9 cps) is observed in the higher activity zone at 24.5 ft. The primary contaminants detected in this borehole include ^{237}Np, ^{233}U, and ^{232}U, which all decay by alpha emission. Naturally occurring ^{232}Th and some decay products throughout the respective decay chains also decay by alpha emission. The lack of a significant neutron flux can probably be attributed to the relatively low activity of these radionuclides and the lack of close proximity to the lighter elements such as F, Na, Mg, O, Si, and Al with sufficient capture cross sections to create the reaction.

Westinghouse Hanford Company acquired spectral gamma data in 1993 in this borehole using the RLS. Additional log data were acquired by Waste Management Federal Services NW with an RLS in 1998. The results are reported in PNNL-11978 (Horton and Randall 1998). ^{233}Pa, ^{239}Pu, and a "waste by-product associated with thorium" were reported. Maximum concentrations for ^{233}Pa and ^{239}Pu were reported as 57 pCi/g and 58 nCi/g, respectively. The comparison plots of RLS and SGLS ^{233}Pa concentrations are similar and suggest no significant changes since 1993. However, current log analysis indicates that no ^{239}Pu exists in the borehole above an MDL of approximately 20 nCi/g. It is likely the 1998 log analysis erroneously interpreted the energy peaks at approximately 375 or 414 keV to be representative of ^{239}Pu. Energy peaks for ^{239}Pu exist at 375.05 and 413.71 keV. ^{233}Pa emits gamma rays at 375.45 and 415.76 keV. The RLS and SGLS cannot distinguish these peaks from one another. However, the concentrations determined from peaks at approximately 375 and 414 keV, when considered to be the result of ^{233}Pa, corroborate the concentrations determined from the 300-, 312-, and 398-keV energy peaks of ^{233}Pa. Therefore, it is unlikely any ^{239}Pu exists in this borehole in any appreciable quantities. The elevated thorium activity reported in the earlier logs is actually an indication of ^{232}U.

The historical total count log data acquired in 1967 and 1976 are consistent with the current SGLS total count data. The 1967 log indicates contamination existed at approximately 25 ft prior to the borehole being drilled. The driller's report in 1967 indicated saturated sediment and"coarse black and white sand" between 25 and 30 ft in depth. Historical log data indicates no significant contamination to a total depth of 212 ft. The borehole was apparently filled to a depth of approximately 48 ft between 1967 and 1976.

The KUT shows slight increases at approximately 28 ft, suggesting a fine-grained sediment layer.

The plots of the repeat logs demonstrate reasonable repeatability of the SGLS data for the naturally occurring and man-made radionuclides.

List of Plots:

References:

Horton, D.G., and Randall, R.R., 1998. *Results of 1998 Spectral Gamma-Ray Monitoring of Boreholes at the 216-Z-1A Tile Field, 216-Z-9 Trench, and 216-Z-12 Crib*, PNNL-11978, Pacific Northwest National Laboratory, Richland, Washington.

U.S. Department of Energy (DOE), 1987. *Final Environmental Impact Statement Disposal of Hanford Defense High-Level, Transuranic and Tank Wastes*, DOE/EIS-0113, Volume 1, Hanford Site, Richland, Washington.

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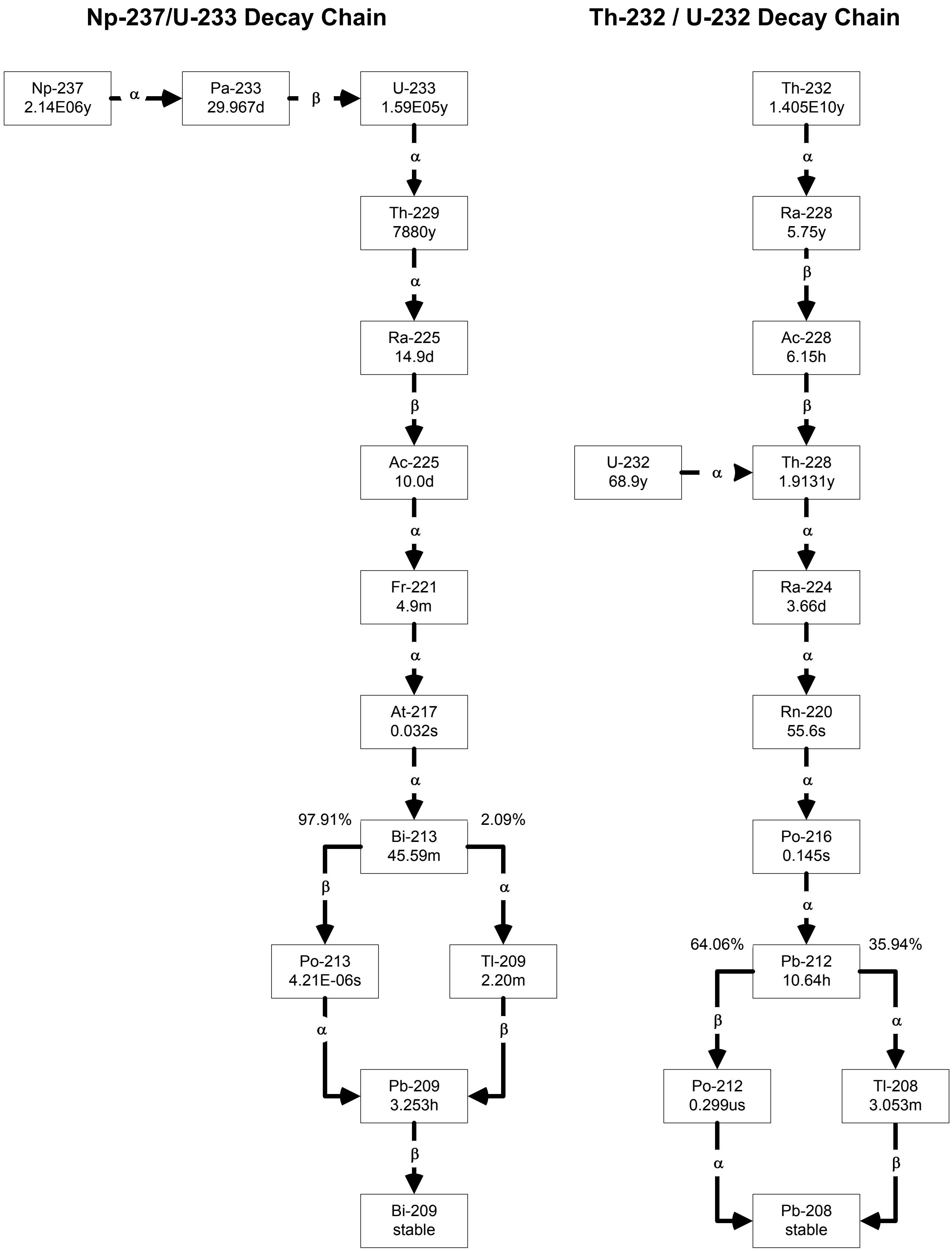
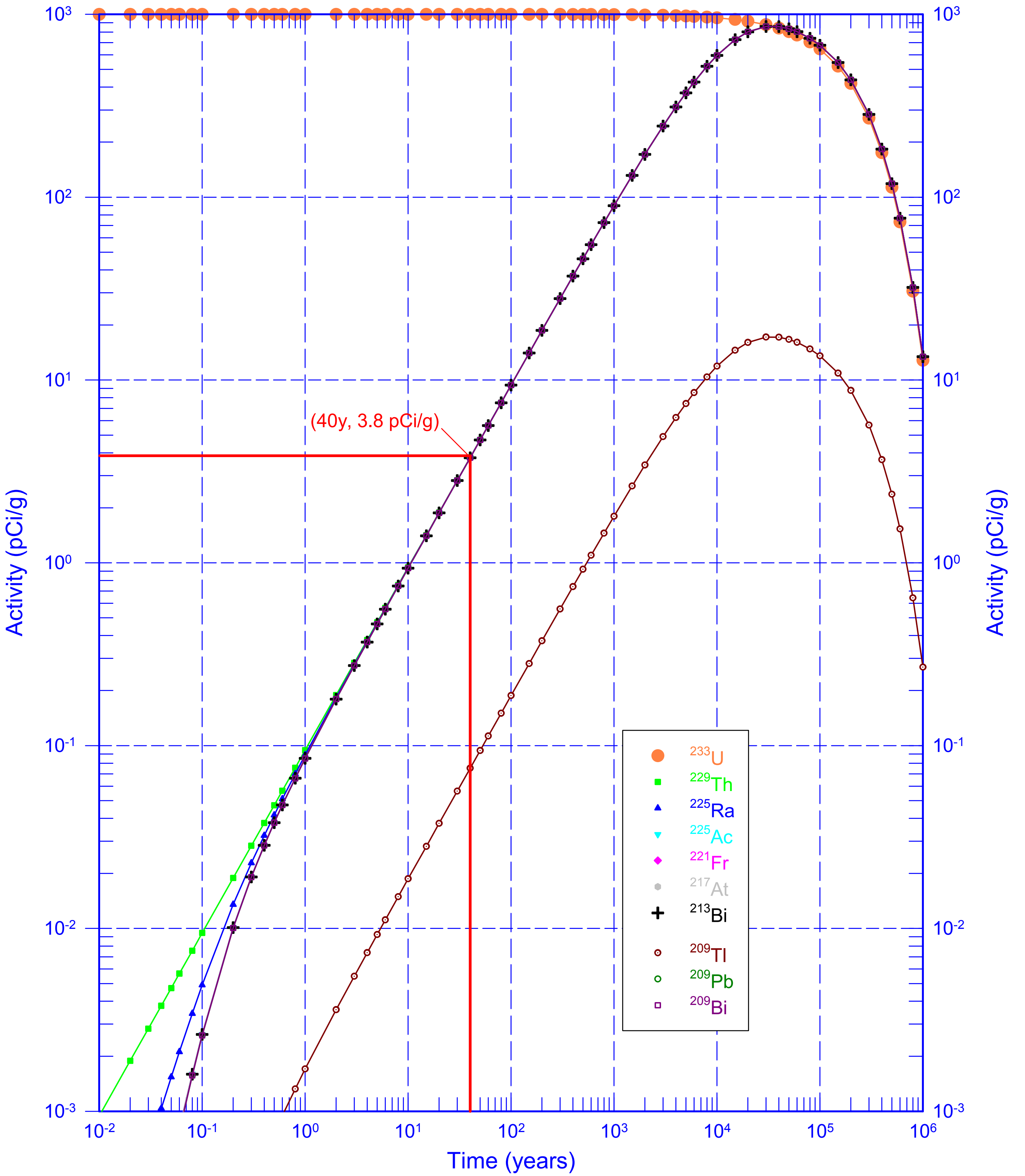
[1] GWL – groundwater level
[2] TOC – top of casing
[3] N/A – not applicable

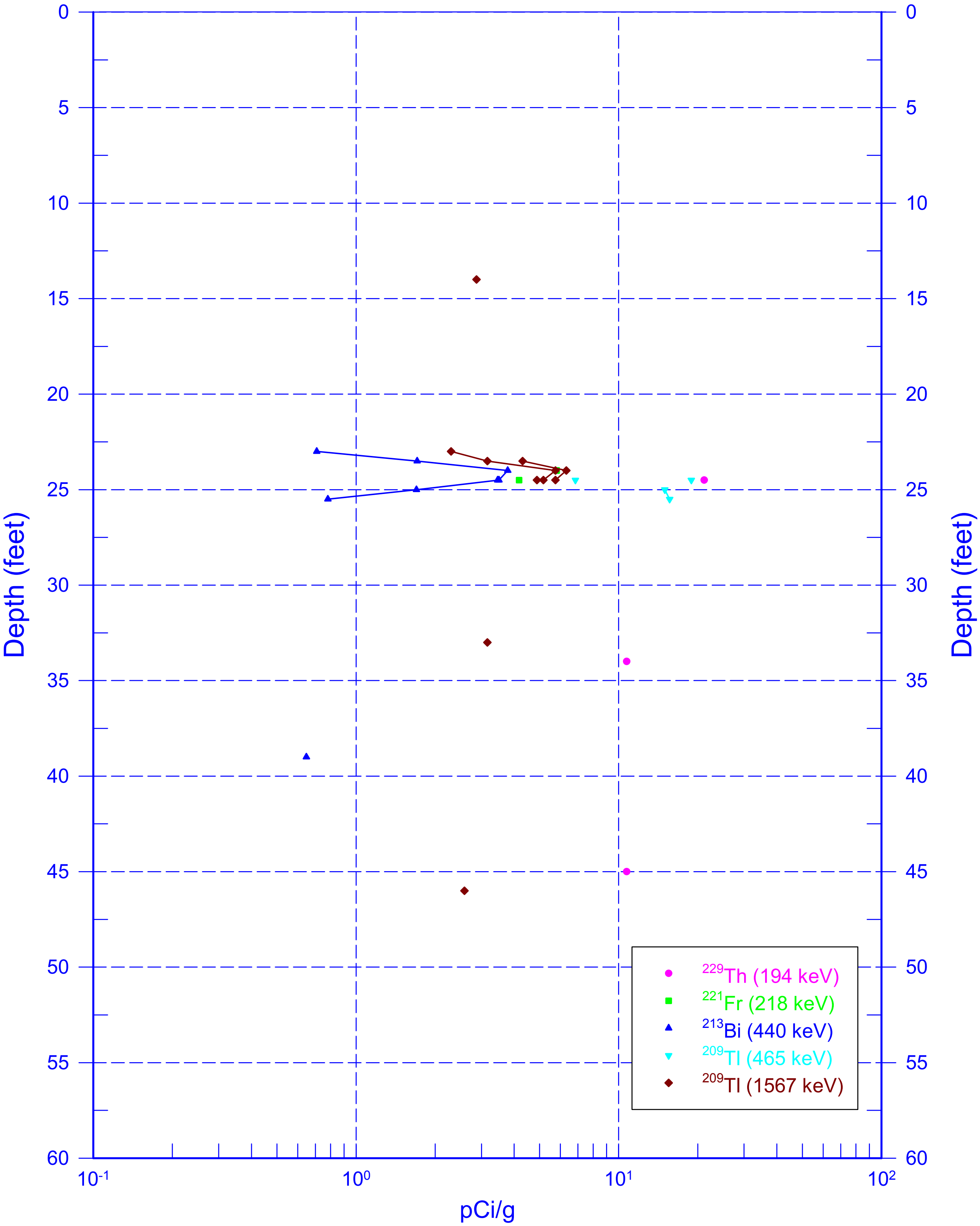
Np-237/U-233 & Th-232 / U-232 Decay Chains



299-W18-08
^{233}U Ingrowth Chart

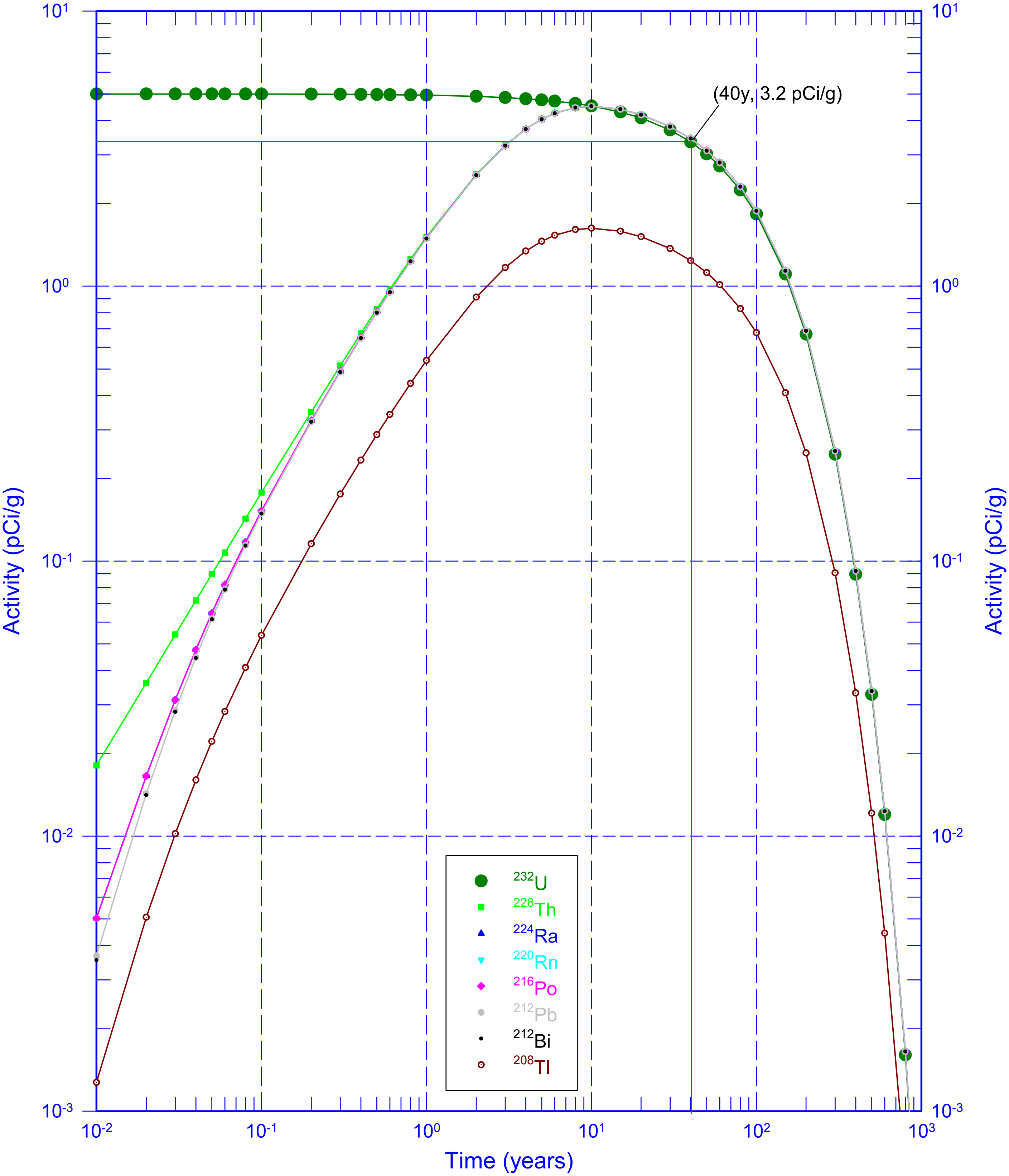


299-W18-08 (A7525)
Comparison of Energy Peaks Detected by the SGLS in the ^{233}U Decay Chain



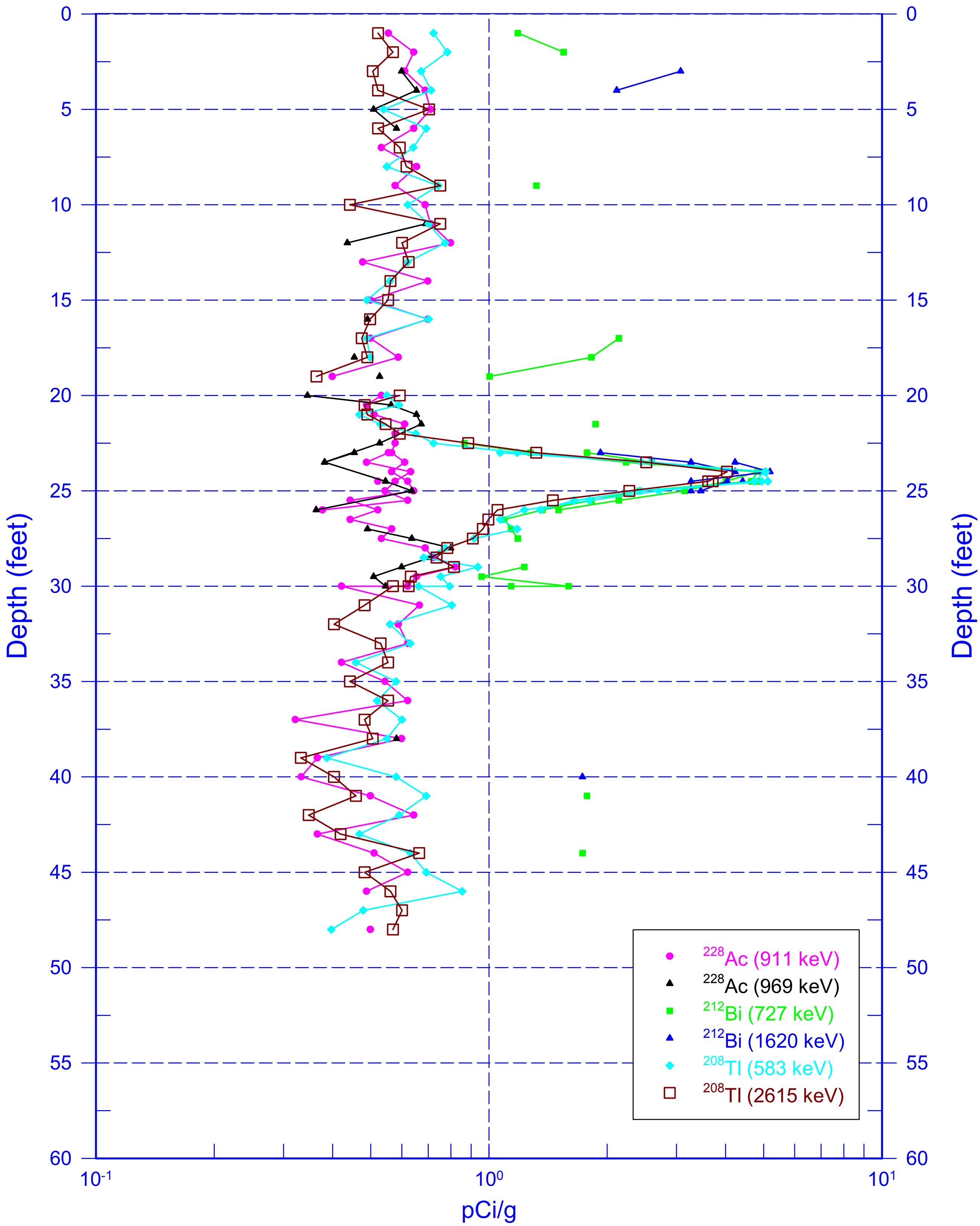
Zero Reference - Top of Casing

299-W18-08
^{232}U Ingrowth Chart



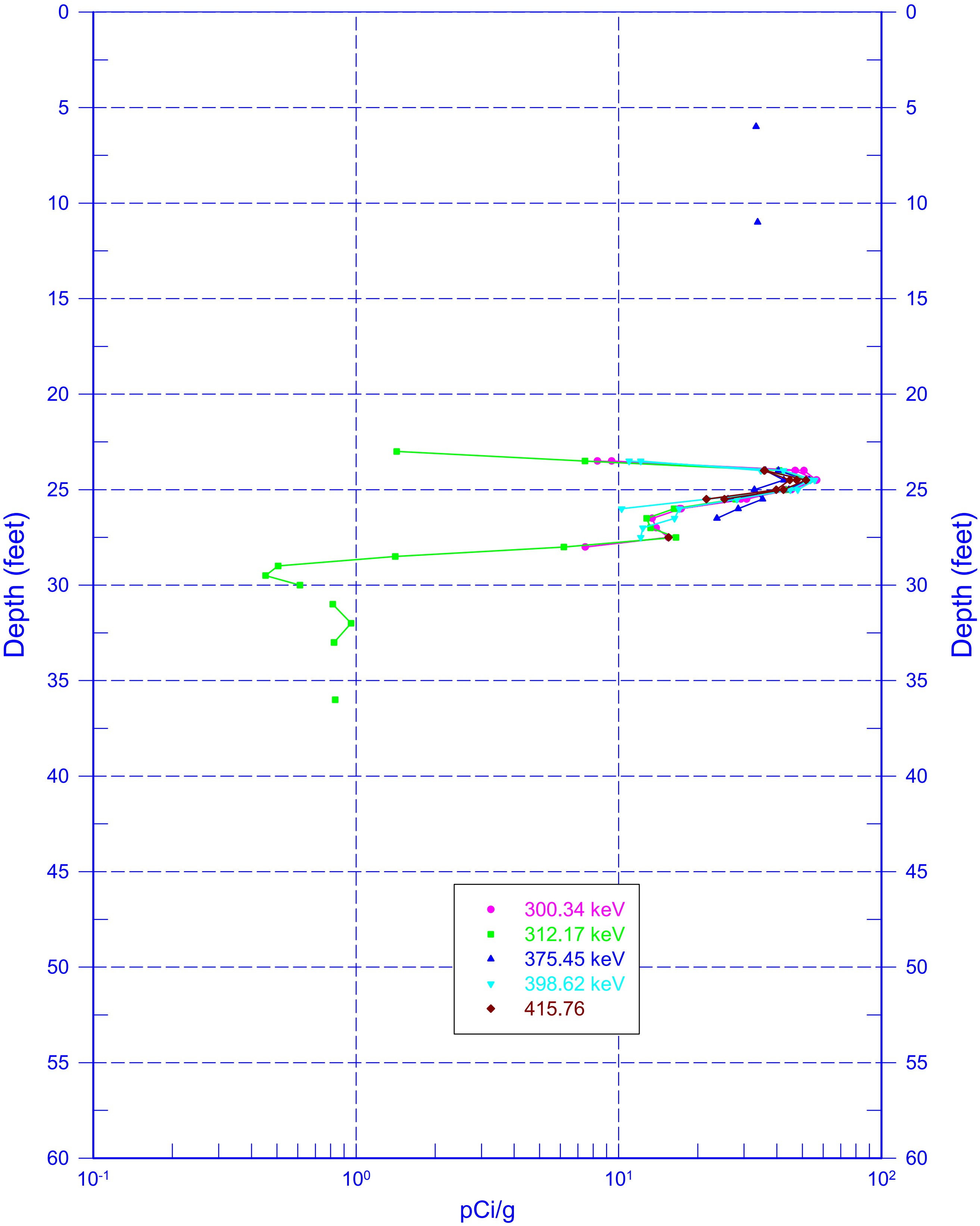
299-W18-08 (A7525)

Comparison of Energy Peaks Detected by the SGLS in the ^{232}U and ^{232}Th Decay Chains



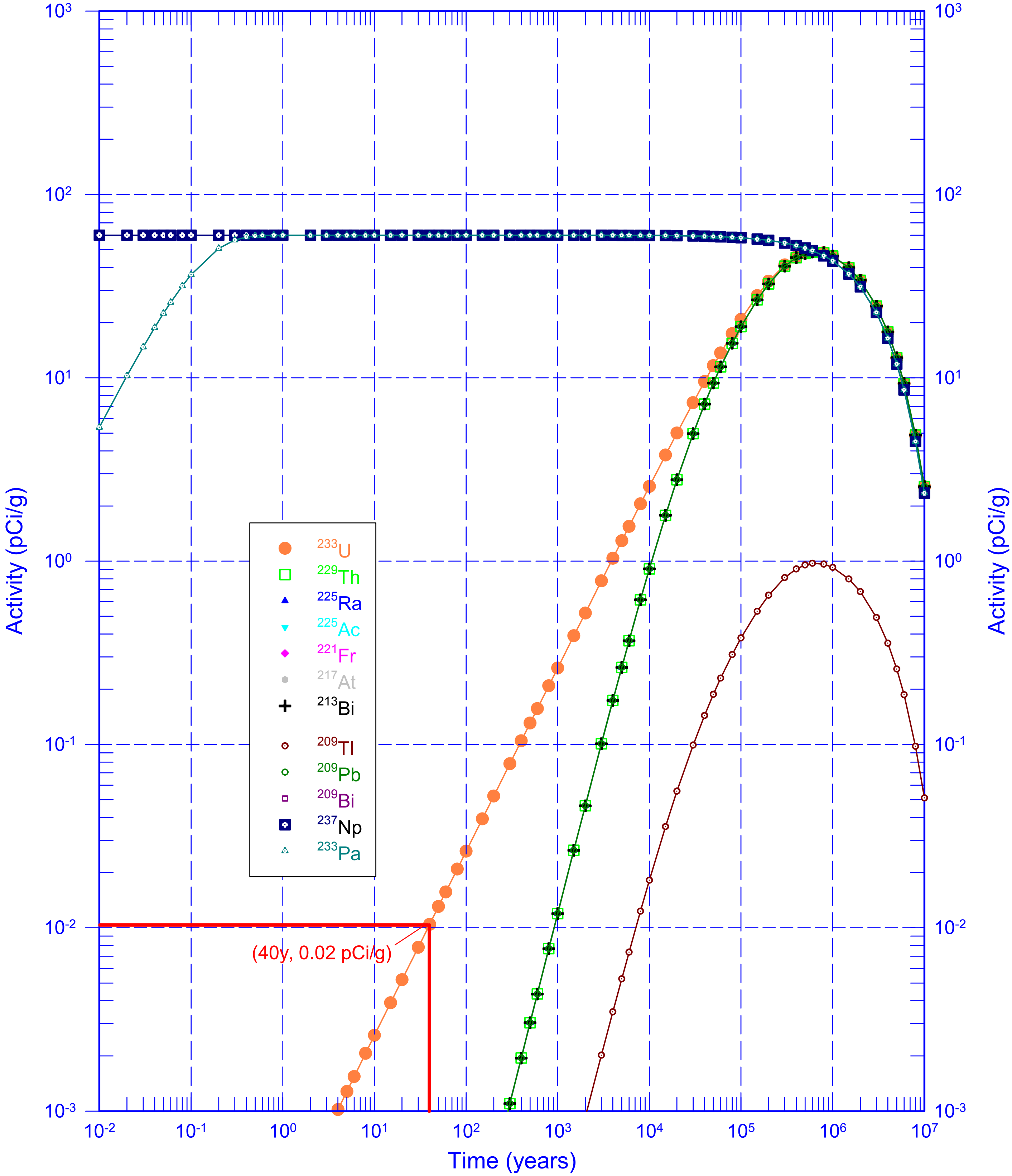
Zero Reference - Top of Casing

299-W18-08 (A7525)
Comparison of Energy Peaks Detected by the SGLS of ^{233}Pa

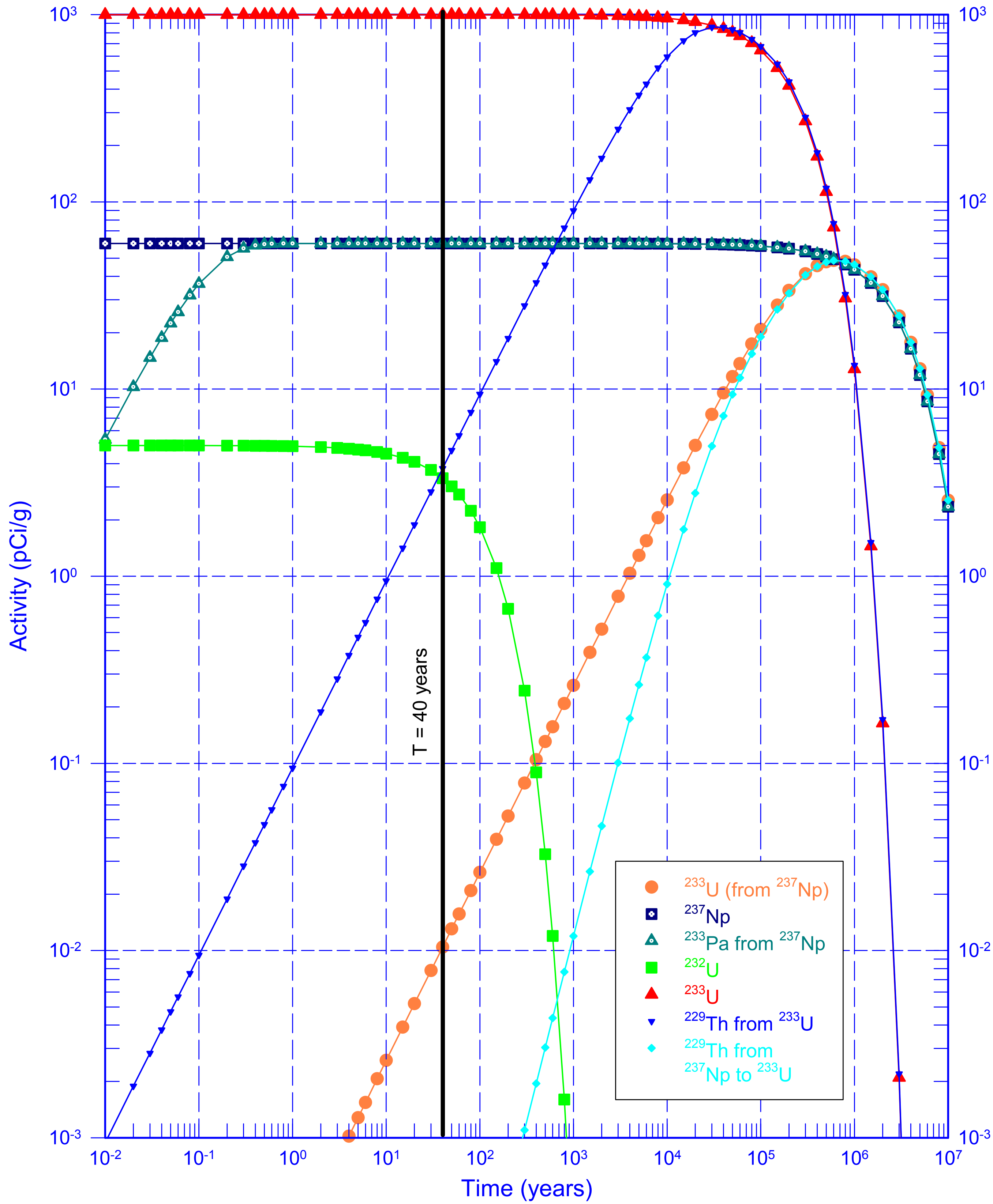


Zero Reference - Top of Casing

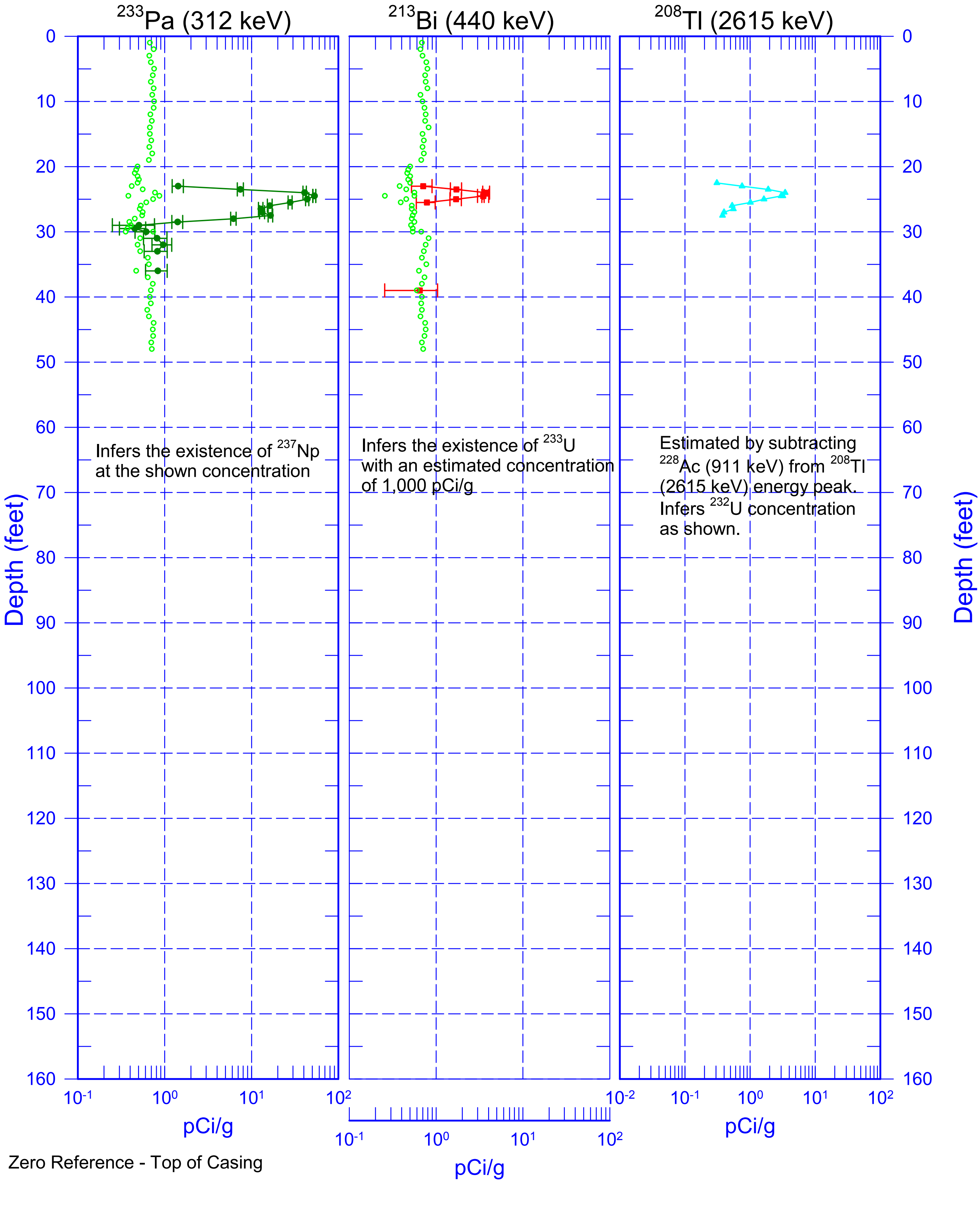
299-W18-08
^{237}Np Ingrowth Chart



299-W18-08
^{237}Np, ^{232}U, & ^{233}U Ingrowth Chart

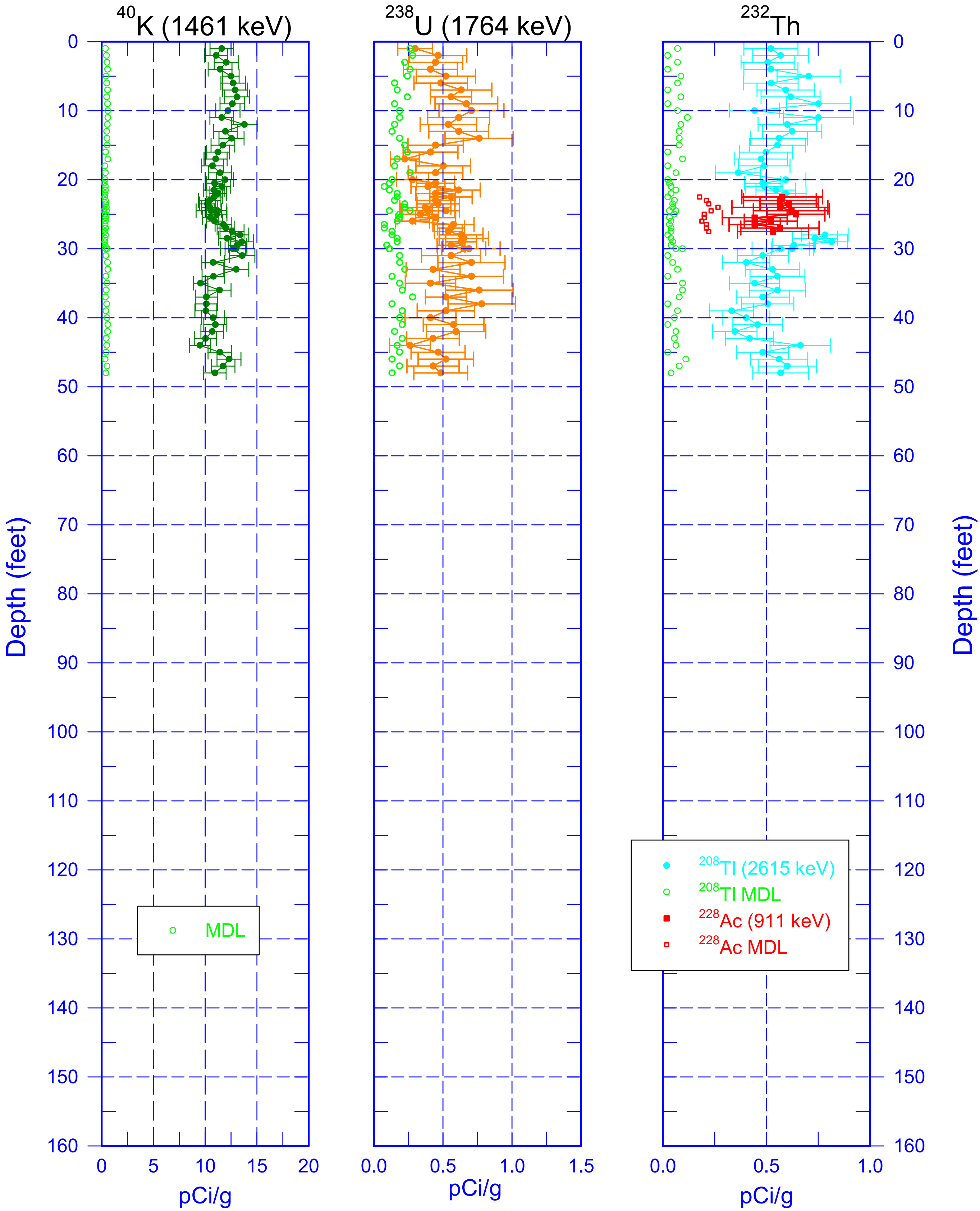


299-W18-08 (A7525)
Man-Made Radionuclides



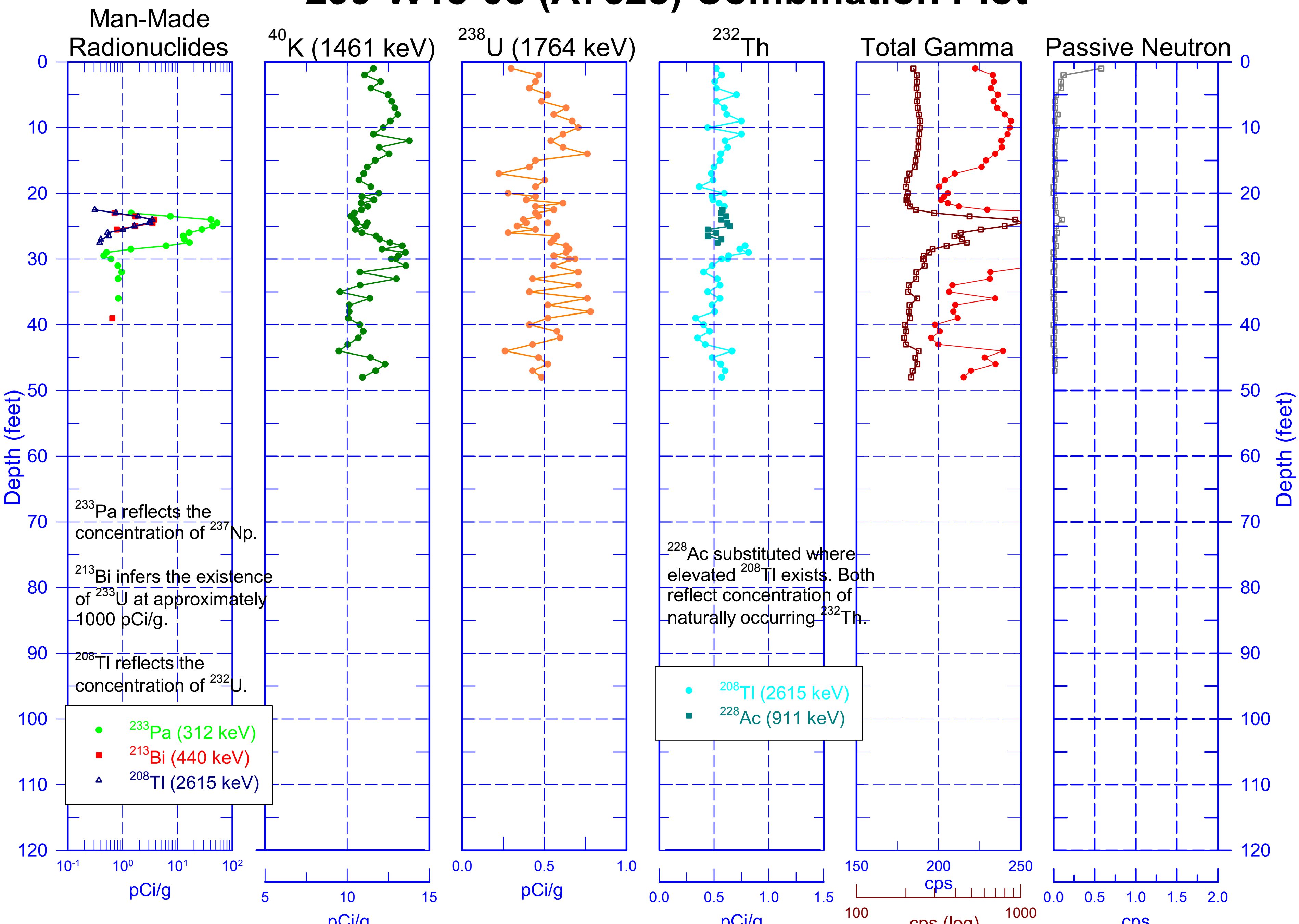
Zero Reference - Top of Casing

299-W18-08 (A7525)
Natural Gamma Logs



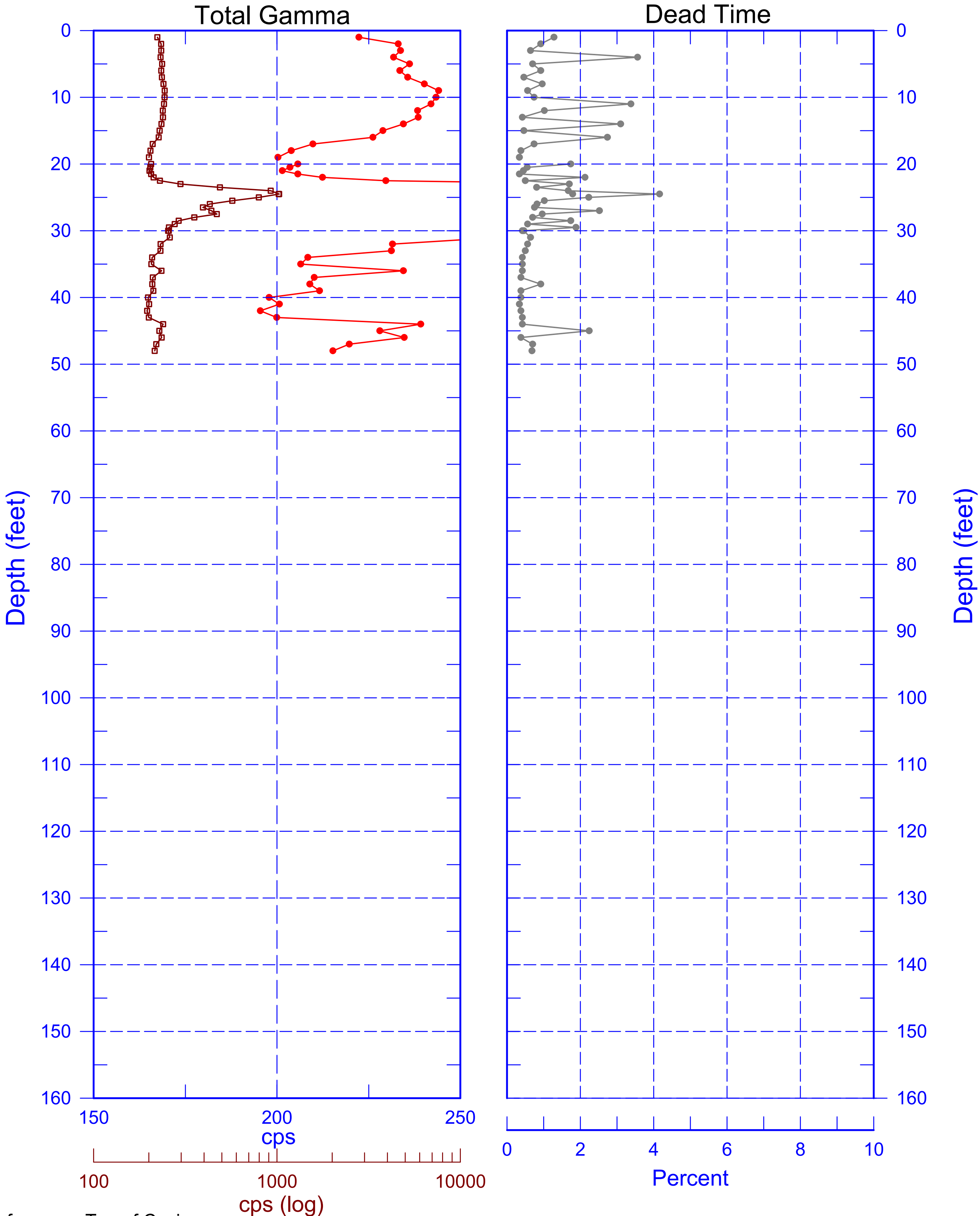
Zero Reference = Top of Casing

299-W18-08 (A7525) Combination Plot



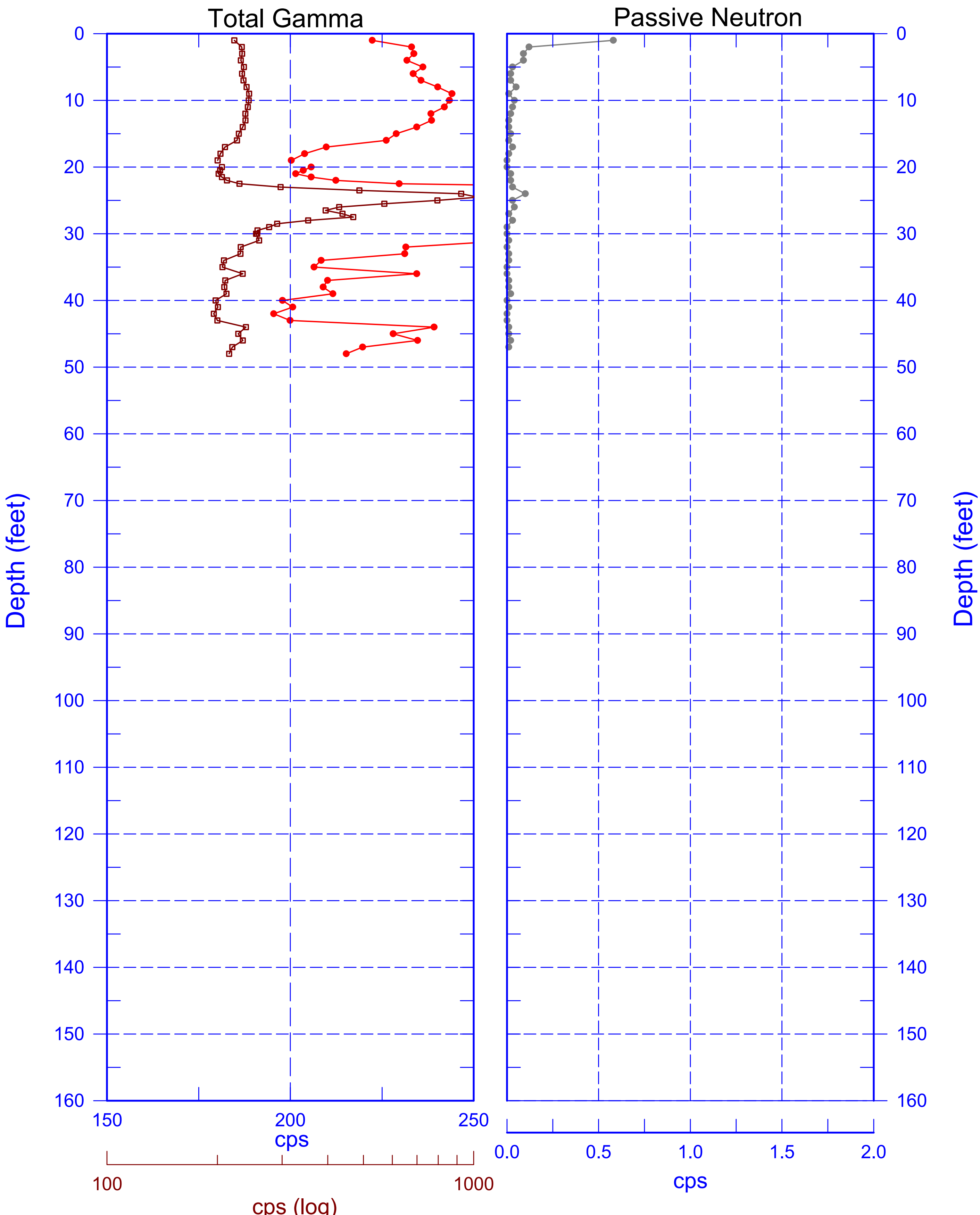
Zero Reference - Top of Casing

299-W18-08 (A7525)
Total Gamma & Dead Time



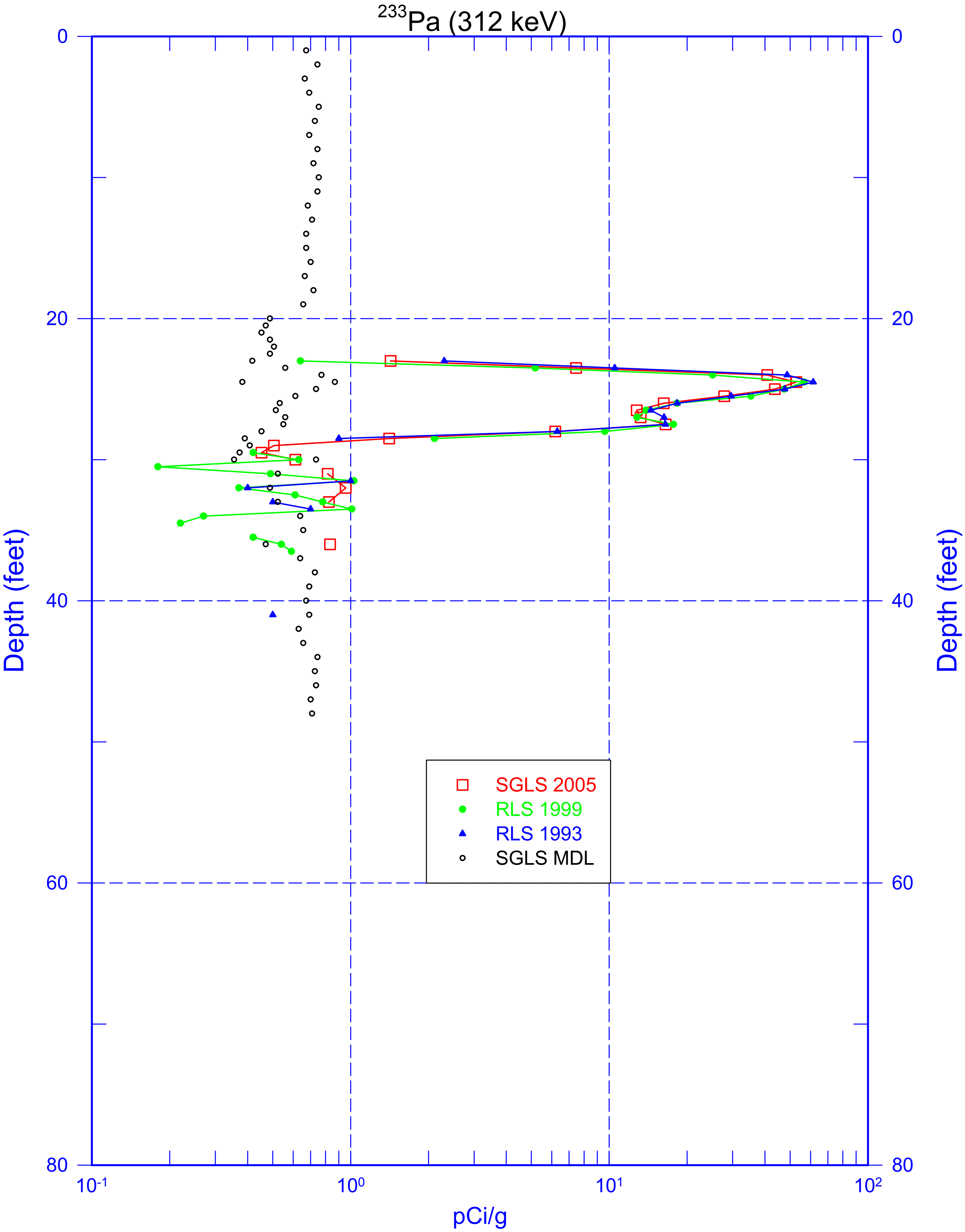
Reference - Top of Casing

299-W18-08 (A7525)
Total Gamma & Passive Neutron



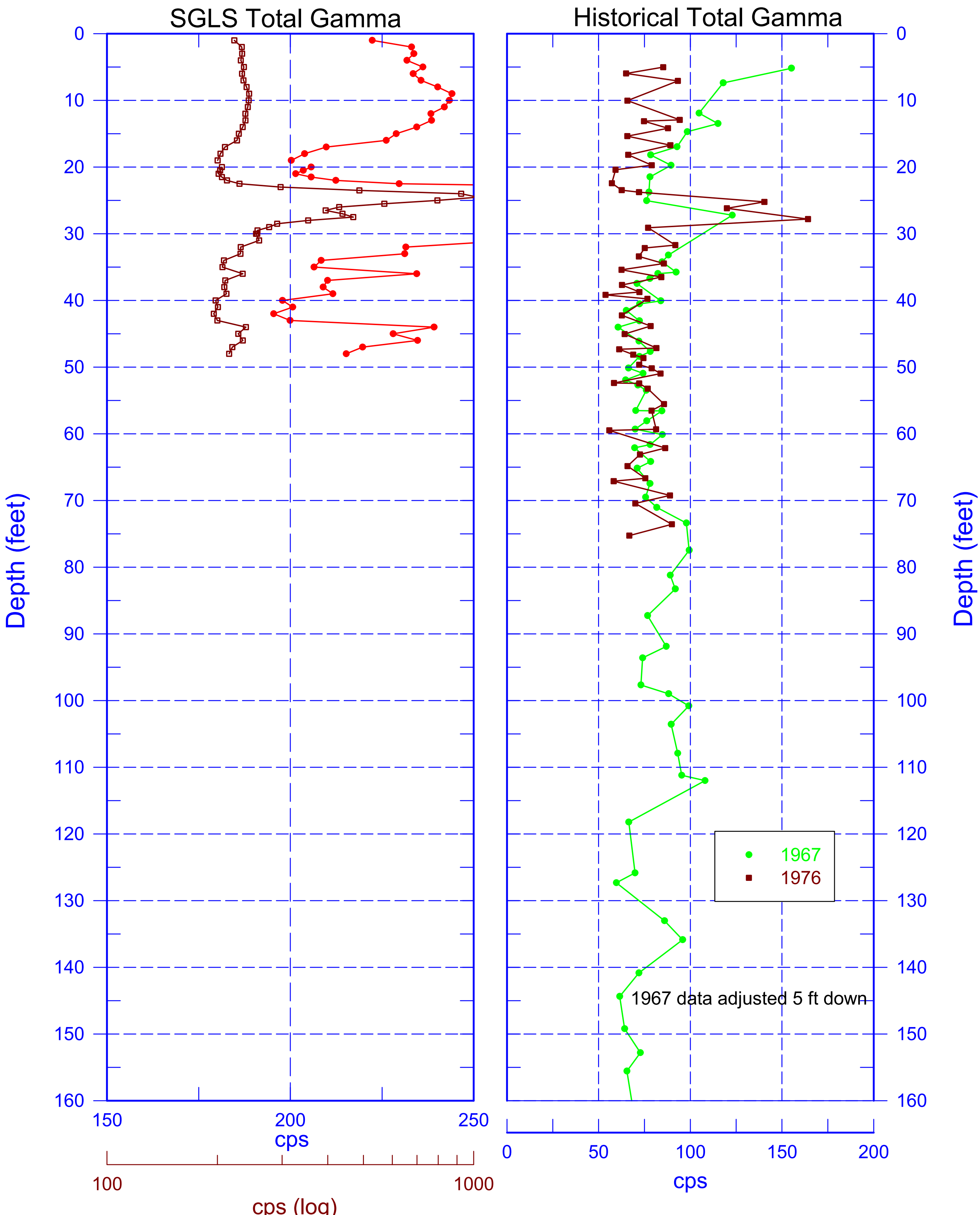
Reference - Top of Casing

299-W18-08 (A7525)
Comparison of RLS (1993 & 1998) and SGLS (2005)



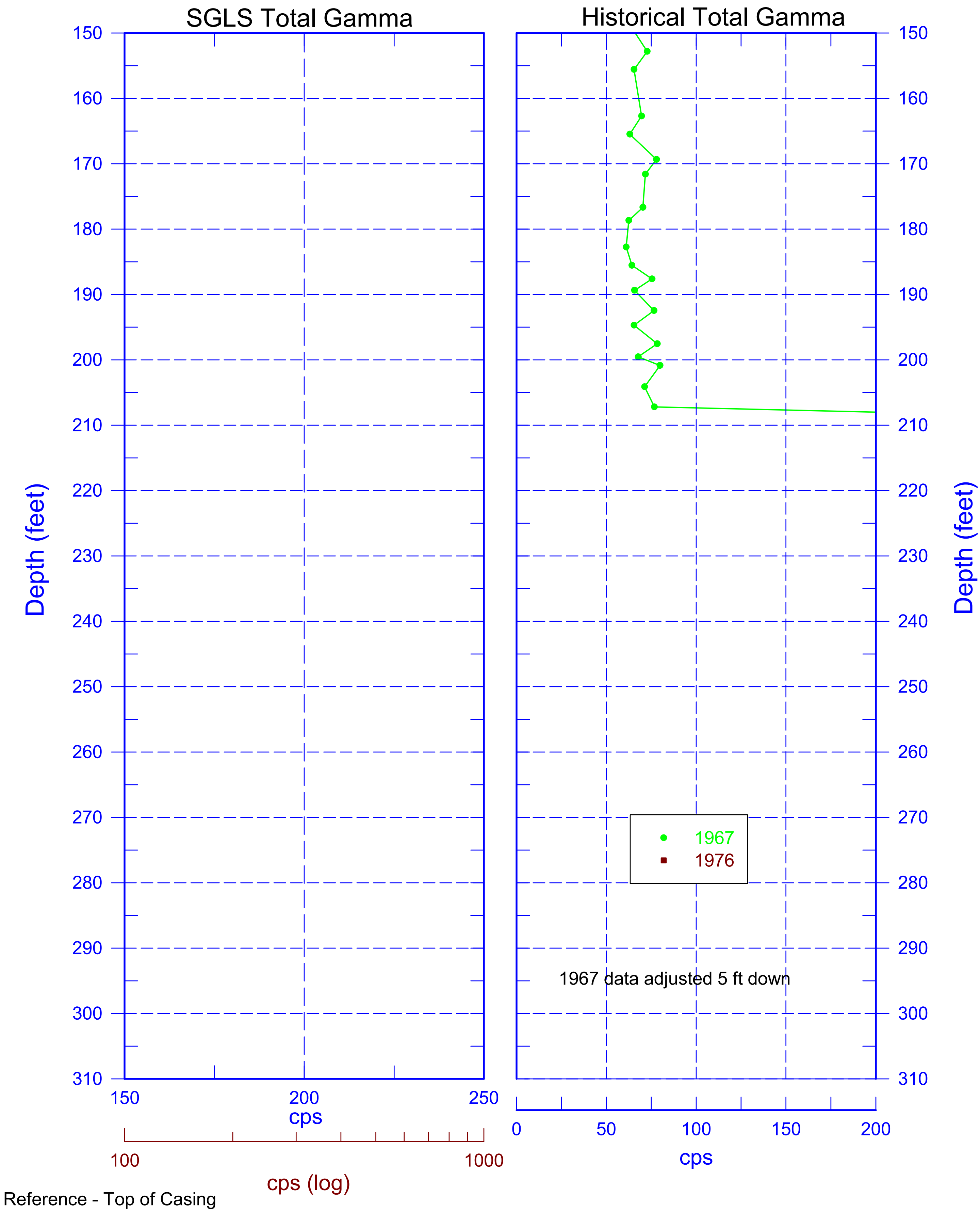
Zero Reference - Top of Casing

299-W18-08 (A7525)
SGLS & Historical Total Gamma



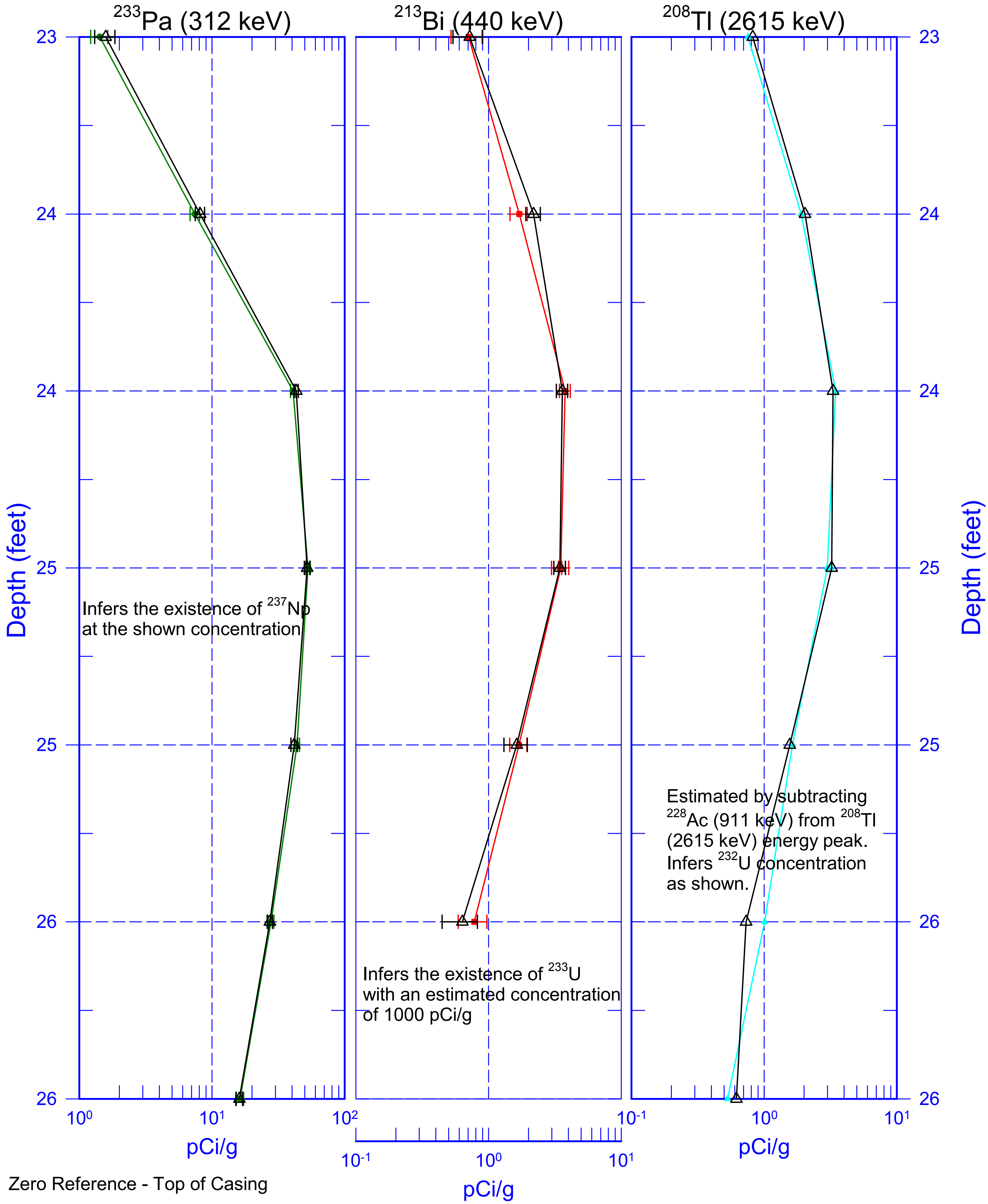
Reference - Top of Casing

299-W18-08 (A7525)
SGLS & Historical Total Gamma



299-W18-08 (A7525)

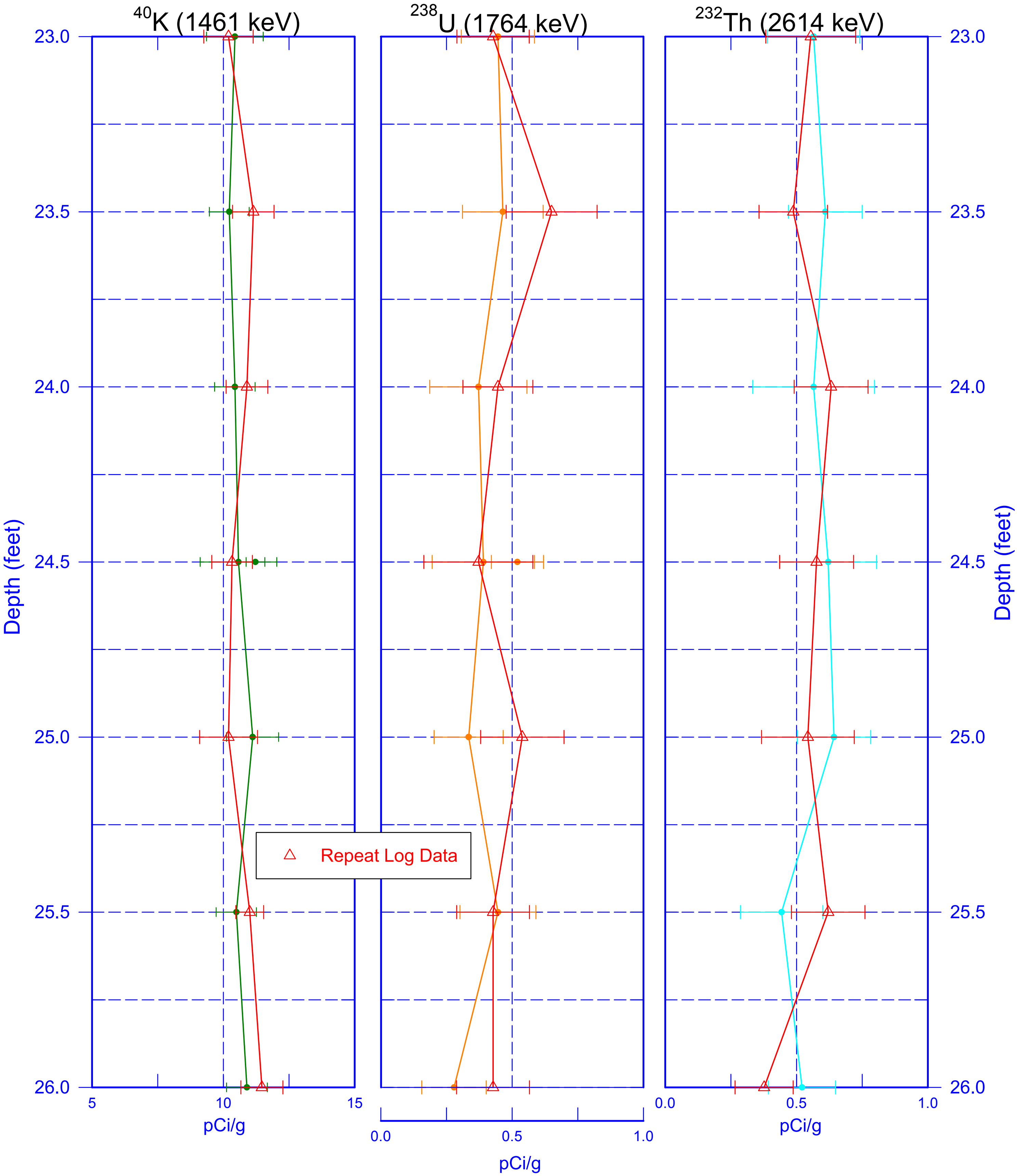
Repeat Section of Man-Made Radionuclides



Zero Reference - Top of Casing

299-W18-08 (A7525)

Repeat Section of Natural Gamma Logs



Zero Reference - Top of Casing